The Association
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HELICAL COIL SPRINGS.

By T. HAYDN WHITEHOUSE and
H. P. CLARKE.

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3/53

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It is obvious that in mechanical designs involving the use of springs these must be considered first as their dimensional limitations will affect to a lesser or greater degree the final arrangement of the mechanism.

Anyone who has had to use springs in problems of this nature will appreciate the difficulties when faced by so many variables. The charts offer in an easily comparable form a complete range of practical helical coil compression and tension springs of up to 1" dia. wire and 12" mean coil diameter in a series of useful stages. Intermediate coil diameter can be obtained by interpolation if necessary. The range is limited to practical proportions by the spring index and Wahls' correction factor so that any spring not falling in the chartered range will not be generally acceptable as a practical component.

When a suitable spring has finally been selected from the charts as much information as possible should be forwarded to the manufacturer when enquiring or ordering. Typical drawing layouts showing a suitable way of doing this are given on sheet 4, and it is recommended that this standard method be adhered to in detailing springs.

Sheet 1 gives relevant formulae and notation as used throughout.

Sheet 2 gives the equivalent formulae for square and rectangular wire, together with information and factors to enable the inch plate and safe load charts to be used. The required inch rate can be read directly off the chart by taking an equivalent size of round wire as shown and multiplying by the appropriate factor as tabulated. The safe load figures are complicated by the fact that the allowable stress varies with the wire sizes on the chart and which is indicated in the various sections. The values upon which the charted figures are based are for hard drawn wire E.N. 49/B, C. & D, range 1 (minimum). Square and rectangular wire is hardened and tempered and the allowable stress will therefore differ. This is usually taken as being 40% of the ultimate tensile stress. In order therefore to obtain the correct safe load the equivalent value for round wire found in Chart II. must be multiplied by the factor found by dividing the stress to be used by the stress allowed on chart. This corrected figure can then be multiplied by the factor θ tabulated.

Sheet 3 gives notes regarding use of charts and a table of safe stresses for hard drawn wire to B.S. 1408/47. E.N. 49 B, C. & D.

On Sheet 4, in addition to the drawing layouts already referred to, will be found a series of details showing the various ends that can be made on compression and extension springs. It should be noted that complete details of the types of ends required should be given to the manufacturers in order that no confusion over misleading terms will occur.

Sheet 5 contains the Inch Rate and Safe Load Charts Nos. I. and II. Chart I. is based on formula 1, sheet 1, and gives the complete range of springs between the spring index values of 3 and 15, 3 at the top. It is inadvisable to use springs with a lesser or greater index than this. The most serviceable size is that with an index of 9 and this series is indicated by the two centre zig-zag heavy lines. The outer pair of heavy lines indicates the series of springs with indexes of 6 to 12. It should be noted that the values given have been computed with $N = 1$ where N is the number of working coils. Therefore to obtain the inch rate for an existing spring, divide the figure given by the number of coils and to find the number of coils for a given rate, divide the figure by the rate required.

The safe load may be read off directly on Chart II. It is based on formula 2, sheet 1, using the values for S_2 as quoted. These are taken from stress values given in B.S. 1408/47 and are the safe allowable stresses given under the minimum values for wire in Range 1, Sheet 3. Safe loads for the other values and ranges can be obtained by multiplying by the factors given on Sheet 3. E.N. 49B is specified as hard drawn patented wire (not for high duty). E.N. 49C is specified as high duty wire (unground). E.N. 49D is specified as high duty wire (ground). The term high duty is specified in B.S. 1408 as wire suitable for valve springs or other applications where it is essential to have the highest possible resistance to fatigue.

Sheet 6 contains the Initial Tension Chart III. which is based on formula 3, Sheet 1, and experimental data published in "Spring Design and Calculations" by John A. Roberts. This book deals very thoroughly with all aspects of spring design and is recommended to all interested in further study of this absorbing topic. We are indebted to Mr. John A. Roberts and Messrs. Herbert Terry & Sons, Ltd., for permission to use the relevant formulae and data. This initial load applies only to extension springs and is the load required to be exerted on the springs before the coils begin to open. When this state is reached the spring thereafter performs as would a compression spring, the inch rate given on Chart I. being the load required to extend the spring and not compress it. It should be noted that this initial tension only occurs with springs made from hard drawn wire as given by B.S. 1408, E.N. 49B, C. & D. Springs which are made with square wire or wire hardened and tempered after coiling have no initial tension and will begin to extend at the inch rate as soon as any load is applied.

HELICAL COIL SPRINGS

ROUND WIRE

FORMULAE:

INCH RATE:-

1. $$x = \frac{Gd^4}{64NR^3} \text{ lbs/inch} \quad \text{(SEE CHART I)}$$

SAFE LOAD:-

2. $$\omega_2 = .1964 \frac{S_2 d^3}{RK} \text{ lbs. (SEE CHART II)}$$

INITIAL TENSION LOAD:-
(EXTENSION SPRINGS)

3. $$\omega_1 = .1964 \frac{S_1 d^3}{R} \text{ lbs. (SEE CHART III)}$$

WHERE

d = WIRE DIAMETER IN INCHES
N = NUMBER OF COILS
R = MEAN RADIUS OF COILS IN INCHES
G = MODULUS OF RIGIDITY
S_1 = INITIAL TENSION STRESS IN LBS/□"
S_2 = SAFE FIBRE STRESS (SEE TABLE) IN LBS/□"

C = SPRING INDEX = $\frac{2R}{d}$

K = WAHL'S CORRECTION FACTOR =

$$\frac{4C-1}{4C-4} + \frac{.615}{C}$$

HELICAL COIL SPRINGS

RECTANGULAR & SQUARE WIRE.

INCH RATE:- $\frac{\beta h^3 b G}{2R^3 \pi N} = \frac{GD^4}{64 NR^3}$ (FOR ROUND WIRE) $\times \lambda$ lbs/inch

SAFE LOAD:- $\frac{S_2 \mu b h^2}{RK} = \frac{.1964\ S_1 d^3}{RK}$ (FOR ROUND WIRE) $\times \theta$ lbs.

WHERE b = LONGER SIDE AND h = SHORTER SIDE IRRESPECTIVE OF WHETHER THE SPRING IS MADE UP WITH THE BAR COILED EDGEWISE OR FLATWISE

NOTE:- S_1 Values allowed in CHART II are not necessarily correct for square wire. To obtain correct value, given figure must be multiplied by a factor obtained by dividing the stress to be allowed by the stress value given in CHART II Allowable stress is taken as 40% of the Ultimate Tensile Stress.

TO FIND INCH RATE OR SAFE LOAD FROM CHART:-

Find Inch Rate or Safe Load of similar round wire spring taking d for Inch Rate as $\sqrt[4]{b \times h^3}$ and d for Safe load as $\sqrt[3]{b \times h^2}$ The values found must then be multiplied by λ (Inch Rate) or θ (Safe Load) as given by $\frac{b}{h}$ in the following table.

TABLE OF VALUES FOR μ, β, λ & θ FOR SQUARE WIRE.

$\frac{b}{h}$	1	1·5	1·75	2·0	2·5	3·0	4·0	6·0	8·0	10	∞
μ	·208	·231	·239	·246	·258	·267	·282	·299	·307	·313	·333
log	T·3181	T·3636	T·3784	T·3909	T·4116	T·4265	T·4502	T·4757	T·4871	T·4955	T·5224
β	·141	·196	·214	·229	·249	·263	·281	·299	·307	·313	·333
log	T·1492	T·2923	T·3304	T·3598	T·3962	T·4200	T·4487	T·4757	T·4871	T·4955	T·5224
λ	1·436	1·996	2·179	2·332	2·536	2·679	2·862	3·045	3·126	3·187	3·390
log	·1571	·3002	·3383	·3677	·4041	·4279	·4566	·4836	·4950	·5034	·5303
θ	1·059	1·176	1·217	1·252	1·313	1·359	1·432	1·523	1·563	1·593	1·695
log	·0249	·0704	·0852	·0977	·1184	·1333	·1560	·1825	·1939	·2023	·2292

HELICAL COIL SPRINGS

NOTES:

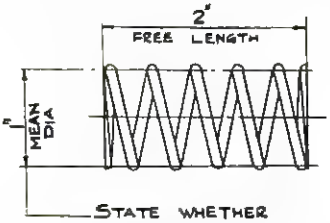
The Inch Rate Chart I is based on Formula 1 and compiled for Carbon Steel Wire and Chrome Vanadium wire where $G = 11.5 \times 10^6$. The figure given at the intersection of the wire dia. and the mean coil dia. must be divided by the number of working coils to give the Inch Rate. Allow 3/4 coil extra each end for squaring off.

The Safe Load Chart II is based on formula 2 where S_1 = allowable safe stress for Hard Drawn Wire EN 49 B.C.+D to B.S. 1408/47. Range 1. To obtain Safe Load for Range 1 max. allowable stress or Ranges 2 & 3 min. or max. allowable stress multiply figure given by factor shown in table below. The allowable safe stress is taken as 40% Ultimate Tensile Stress.

The Initial Load Chart III is based on formula 3 and applies to the Initial Tension Load on Extension Springs. This figure must be considered when finding the extension under load, but does not affect the Inch Rate. Square or Rectangular wire is hardened and tempered after coiling and has no initial tension.

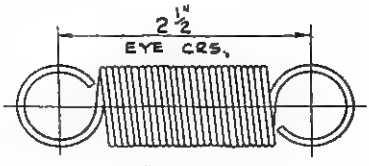
TABLE OF SAFE STRESSES. Hard Drawn Wire EN 49 B.C.+D

Wire Dias	Range 1.		Range 2		Range 3.		
	Min.	Max.	Min.	Max.	Min.	Max.	
0·53 to ·023	116,500	–	125,000	–	135,000		lbs/□"
	1		1·08		1·16		factor
024 to ·034	107,000	116,500	116,500	125,000	125,000	135,000	lbs/□"
	1	1·08	1·08	1·17	1·17	1·26	factor
·035 to ·052	98,500	107,000	107,000	116,500	116,500	125,000	lbs/□"
	1	1·09	1·09	1·18	1·18	1·27	factor
·053 to ·086	89,500	98,500	98,500	107,500	107,500	116,500	lbs/□"
	1	1·1	1·1	1·2	1·2	1·3	factor
·087 to ·136	80,500	89,500	89,500	98,500	98,500	107,500	lbs/□"
	1	1·11	1·11	1·22	1·22	1·34	factor
·137 to ·202	71,500	80,500	80,500	89,500	89,500	98,500	lbs/□"
	1	1·13	1·13	1·25	1·25	1·38	factor
·203 to ·264	62,500	71,500	71,500	80,500	80,500	89,500	lbs/□"
	1	1·14	1·14	1·29	1·29	1·43	factor
·265 to ·400	62,500	–	62,500	71,500	71,500	80,500	lbs/□"
	1		1	1·14	1·14	1·29	factor



— DATA —

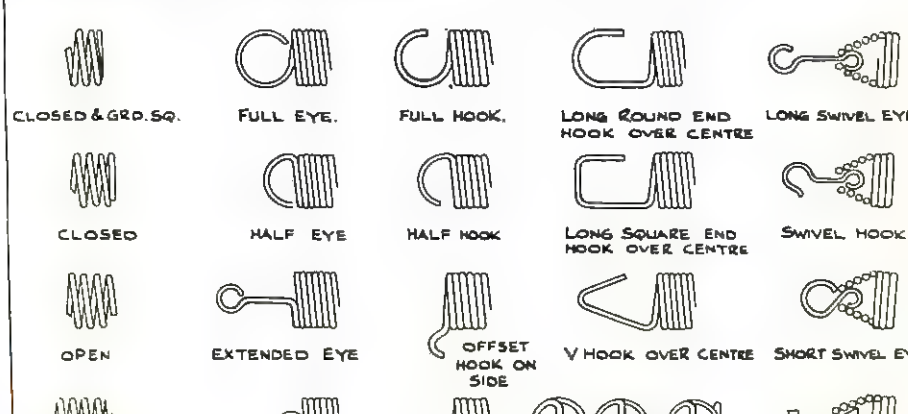
MATL: CARBON STEEL EN 49 B RANGE 1
DIA. OF WIRE :- 11 S.W.G.
No. OF WORKING COILS :- 5.
TOTAL No. OF COILS :- 6½.
ENDS CLOSED AND GROUND SQ
INITIAL COMPRESSION :- 3/16"
TOTAL WORKING COMP'N. :- ½"
INCH RATE :- 52 lb.
SAFE LOAD :- 42 lb.
FINISH :- SELF COLOUR



NOTE:- EYE DIA IS NORMALLY SAME DIA. AS SPRING. IF HOOKS ARE REQUIRED SPECIFY WIDTH OF OPENING.

— DATA —

MATL: CARBON STEEL EN 49 B RANGE 1
DIA. OF WIRE :- 14 S.W.G.
No OF COILS :- 26.
FULL ROUND EYES EACH END IN LINE OVER CENTRE.
INITIAL EXTENSION :- ½"
TOTAL EXTENSION :- 1¼.
INCH RATE :- 7 lb.
SAFE LOAD :- 23 lb.
FINISH :-
BLACK ENAMEL.



ENDS FOR COMPRESSION SPRINGS

EYES ARE CLOSED - HOOKS ARE OPEN
FULL EYES OR HOOKS AT CENTRE OR SIDE.
HALF EYES OR HOOKS AT CENTRE
ENDS FOR TENSION SPRINGS.

CONED ENDS FOR SWIVEL FIXINGS

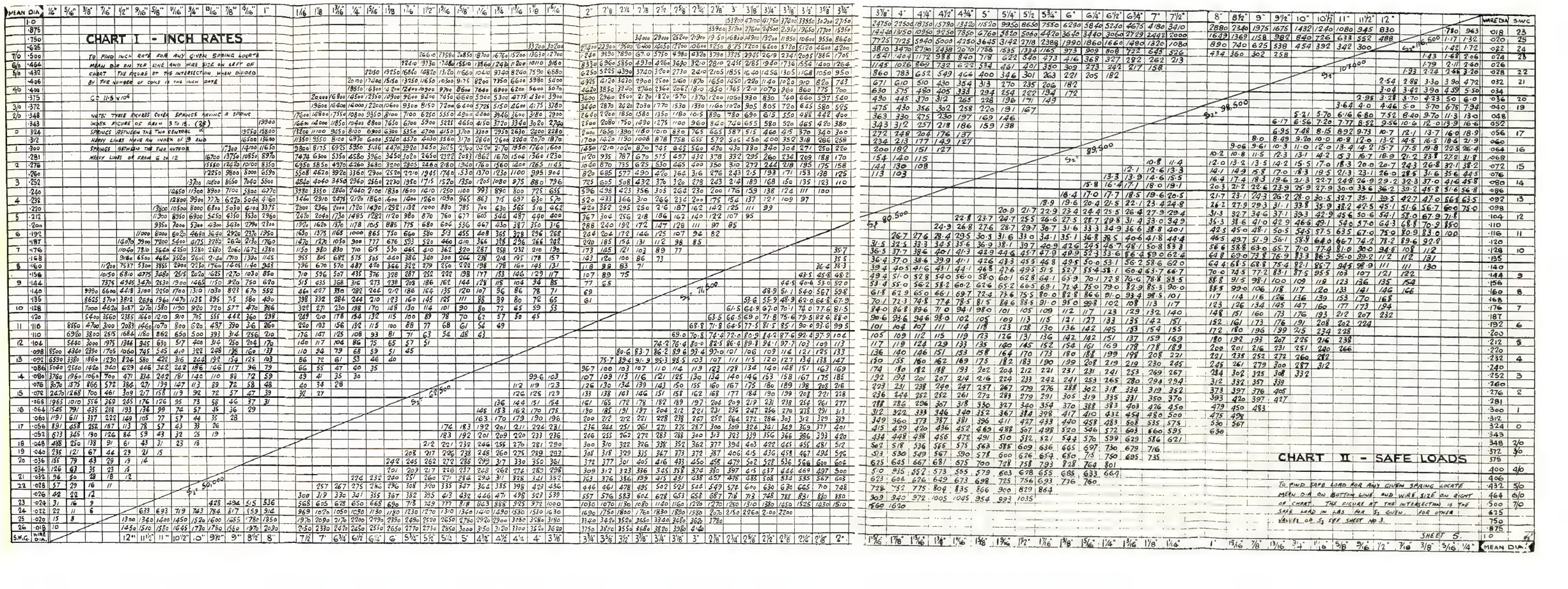


CHART I - INCH RATES
TO FIND INCH RATE FOR ANY GIVEN SPRING LOCATE MEAN DIA ON TOP LINE AND WIRE SIZE ON LEFT OF CHART. THE FIGURE AT THE INTERSECTION WHEN DIVIDED BY THE NUMBER OF COILS IS THE INCH RATE
C = 11.5 x 10⁶
NOTE: THESE FIGURES COVER SPRINGS HAVING A SPRING INDEX FIGURE OF BARK 3 TO 15. (8)
SPRINGS BETWEEN THE TUB BOTTOM AND HEAVY LINES ARE FROM 6 TO 12
SPRINGS BETWEEN THE TUB BOTTOM AND HEAVY LINES ARE FROM 6 TO 12
CHART II - SAFE LOADS
TO FIND SAFE LOAD FOR ANY GIVEN SPRING LOCATE MEAN DIA ON BOTTOM LINE AND WIRE SIZE ON RIGHT OF CHART. THE FIGURE AT THE INTERSECTION IS THE SAFE LOAD IN LBS FOR S₁ GIVEN. FOR OTHER VALUES OF S₁ SEE SHEET NO 3.
SHEET 5.

SWG	MEAN DIA	¼"	5/16"	⅜"	7/16"	½"	9/16"	⅝"	11/16"	¾"	13/16"	⅞"	15/16"	1"
	·240								197·5	181·5	150·5	140·0	130·5	122·5
4	·232								178·5	164·0	136·0	126·5	118·0	110·5
	·220							167·5	152·0	125·5	116·0	108·0	100·5	83·8
5	·212							150·0	136·5	112·5	108·0	86·4	80·2	75·3
	·200							125·9	106·0	94·3	87·1	72·0	67·3	63·0
6	·197						123·5	111·5	91·0	83·5	77·0	63·5	59·4	55·6
	·187					128·5	114·5	92·4	84·1	77·5	63·4	58·8	55·4	46·2
7	·176					107·2	95·3	77·2	70·2	64·2	52·9	49·1	45·8	38·5
	·168					92·9	74·5	67·1	60·9	49·7	48·8	42·6	35·6	33·4
8	·160				91·8	80·3	61·7	57·9	52·6	43·0	39·7	33·0	30·8	28·9
	·156				85·2	74·7	59·7	53·7	43·5	39·8	36·8	30·6	28·5	24·2
9	·144				67·1	52·7	47·0	37·6	34·2	32·1	25·9	24·3	20·3	19·1
	·140			71·8	61·5	48·6	43·2	34·7	31·5	25·6	23·8	21·4	18·7	17·6
	·135			64·4	55·2	43·5	28·7	31·1	28·2	23·2	21·4	18·0	16·8	15·7
10	·128			5·49	42·4	37·2	29·5	26·5	21·6	19·8	18·3	15·3	14·3	12·1
	·120			45·4	34·9	30·6	24·2	21·7	17·81	16·3	13·6	12·6	10·6	9·95
11	·116		49·1	40·9	31·5	24·6	21·9	17·8	16·01	13·3	12·3	10·3	9·6	8·01
	·110		41·8	34·9	26·9	21·0	18·7	15·0	13·7	11·4	10·5	8·15	7·27	6·83
12	·104		35·3	26·5	22·5	17·7	14·1	12·7	10·4	9·54	7·90	7·37	6·16	5·08
	·098	36·9	29·6	22·1	16·9	14·8	11·8	10·6	8·71	7·21	6·64	5·50	4·57	4·28
13	·092	30·6	22·0	18·4	14·0	11·0	9·78	7·94	6·51	5·97	4·93	4·56	3·79	3·75
	·086	25·0	18·0	13·4	11·5	9·0	7·23	6·51	5·33	4·36	4·03	3·32	2·84	2·43
14	·080	21·5	14·5	10·8	8·03	7·24	5·81	4·72	3·82	3·12	2·88	2·45	2·09	1·77
	·076	15·5	12·4	9·21	7·08	5·62	5·00	4·06	3·28	2·67	2·16	2·10	1·79	1·52
15	·072	13·2	9·41	7·85	6·02	4·76	3·82	3·07	2·48	2·27	1·97	1·63	1·43	1·15
	·068	11·1	7·96	5·93	4·59	4·01	3·20	2·58	2·09	1·76	1·48	1·24	1·04	·87
16	·064	9·24	6·59	4·90	3·81	3·00	2·39	1·89	1·45	1·33	1·23	·92	·72	
	·060	7·67	5·46	4·08	3·16	2·20	1·76	1·45	1·09	1·00	·92	·68		
17	·056	5·52	3·97	2·99	2·30	1·80	1·42	1·17	·88	·81	·68			
	·052	4·41	3·14	2·39	1·64	1·28	1·04	·86	·63	·58	·47			
18	·048	3·48	2·23	1·70	1·29	·92	·75	·61	·44	·40				
19	·040	1·80	1·18	·88	·61	·43	·35	·28						
20	·036	1·19	·77	·57	·41	·29	·23							
	·034	1·00	·65	·44	·31	·22								
21	·032	·75	·48	·33	·23	·18								
22	·028	·45	·30	·203	·14									
	·026	·32	·21	·145										
23	·024	·25	·153	·102										
24	·022	·178	·094											
25	·020	·122	·070											
26	·018	·081	·050											
27	·016	·051												
	·015	·037												
28	·014	·031												

SWG	1 1/16"	1⅛"	1 3/16"	1¼"	1 5/16"	1⅜"	1 7/16"	1½"	1 9/16"	1⅝"	1 11/16"	1¾"	1 13/16"	1⅞"	1 15/16"
	102·7	96·6	91·6	77·9	74·3	71·0	67·9	65·0	57·5	54·3	52·4	50·5	43·9	42·4	41·1
4	92·7	87·5	82·6	70·6	67·3	64·2	61·4	53·1	51·1	49·1	47·2	41·1	39·7	38·4	37·2
	79·0	74·5	63·2	60·0	57·4	54·6	47·3	45·3	43·5	41·8	36·3	35·0	33·8	32·7	28·2
5	70·7	66·9	56·6	53·9	51·3	44·3	42·4	40·6	38·9	33·9	32·6	31·4	27·0	26·1	25·3
	53·0	50·3	47·6	45·1	38·8	37·1	35·4	30·7	29·5	28·4	27·3	23·5	22·6	21·9	18·9
6	47·1	44·4	42·0	36·1	34·3	32·8	31·4	27·2	26·0	25·0	21·4	20·7	20·0	17·2	16·7
	43·5	41·1	35·2	33·4	31·8	30·3	26·2	25·1	24·1	20·7	19·9	19·2	16·5	15·9	15·4
7	36·2	30·9	29·2	27·8	23·9	22·8	21·8	18·7	17·9	17·2	16·5	14·2	13·7	12·2	11·8
	31·4	26·8	25·4	21·6	20·7	19·8	16·9	16·2	15·6	13·3	12·8	12·4	10·9	10·6	9·34
8	25·6	23·2	19·9	18·9	18·0	15·3	14·6	14·0	12·0	11·5	11·10	9·78	9·45	8·38	8·06
	22·8	21·5	18·4	17·5	14·8	14·2	13·5	11·6	11·1	10·7	9·40	9·08	7·99	7·72	7·47
9	18·0	15·3	14·5	12·3	11·7	11·1	9·46	9·10	8·00	7·70	7·41	6·52	6·29	5·50	5·33
	14·9	14·1	11·9	11·3	10·6	9·09	8·60	7·66	7·29	6·45	6·21	5·43	5·24	5·02	4·38
	13·3	12·6	10·6	10·1	8·56	8·16	7·16	6·86	6·01	5·78	5·56	4·86	4·69	4·04	3·91
10	11·4	9·58	9·08	7·66	7·31	6·39	6·12	5·35	5·13	4·46	4·30	3·70	3·57	3·08	2·99
	8·35	7·87	6·66	6·31	5·51	5·26	4·60	3·98	3·83	3·68	3·16	3·05	2·62	2·54	
11	7·54	6·36	6·00	5·22	4·97	4·26	4·17	3·99	3·08	2·96	2·53	2·46			
	5·70	5·41	4·69	4·46	3·87	3·70	3·21	2·74	2·34	2·26	2·17				
12	4·82	4·17	3·96	3·43	2·96	2·83	2·46	2·06	1·98						
	3·70	3·50	3·31	2·60	2·48	2·11	1·80								
13	3·06	2·64	2·30	2·14	1·83	1·56									
	2·28	1·96	1·85	1·57	1·33										
14	1·67	1·41	1·33	1·13											
	1·28	1·21	1·02												
15	·97	·91													
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24															
25															
26															
27															
28															

SWG	2"	2 1/16"	2¼"	2 3/16"	2 1/8"	2 5/16"	2¾"	2 7/16"	3"	3 1/16"	3¼"	3 3/16"	3 1/8"	3 5/16"	3¾"
	35·4	33·4	28·1	26·6	23·1	22·0	19·2	18·3	15·9	15·3	13·1	12·8	10·9	10·5	
4	32·1	30·1	25·3	24·0	20·9	18·2	17·3	15·1	12·9	12·3	11·9	10·2	9·81		
	27·3	22·8	21·6	18·8	16·3	15·5	13·4	12·8	11·0	10·5	9·08				
5	21·8	20·6	17·8	16·8	15·6	12·6	12·0	10·3	8·76	8·40					
	18·3	15·7	13·6	12·8	11·0	10·5	8·97	7·65	7·34						
6	14·8	13·9	12·1	10·3	9·76	8·30	7·09	6·76							
	13·7	11·7	10·1	9·51	8·06	7·69	6·55								
7	11·6	9·79	7·47	7·06	6·72	5·71									
	9·03	7·70	6·50	6·15	5·21										
8	7·06	5·94	5·61	4·75											
	6·55	5·50	4·64												
9	4·60	3·86													
	3·78														
	3·38														
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CHART III INITIAL TENSION LOADS

(EXTENSION SPRINGS)

THE ABOVE TABLE GIVES THE INITIAL LOADING FOR TENSION SPRINGS AND SHOULD BE USED IN CONJUNCTION WITH INCH RATE CHART I THE FIGURES GIVEN ABOVE SHOULD BE CONSIDERED WITH THE TOTAL LOAD ON THE SPRING AND DOES NOT AFFECT THE INCH RATE

E.G. TENSION SPRING 13 SWG WIRE ½" M. DIA. 20 COILS RATE FROM CHART I = 41·2 lb THEN LOAD TO EXTEND SPRING L INCHES = L × 41·2 + 11 lb INITIAL LOAD FROM CHART III